

GREENFLOW

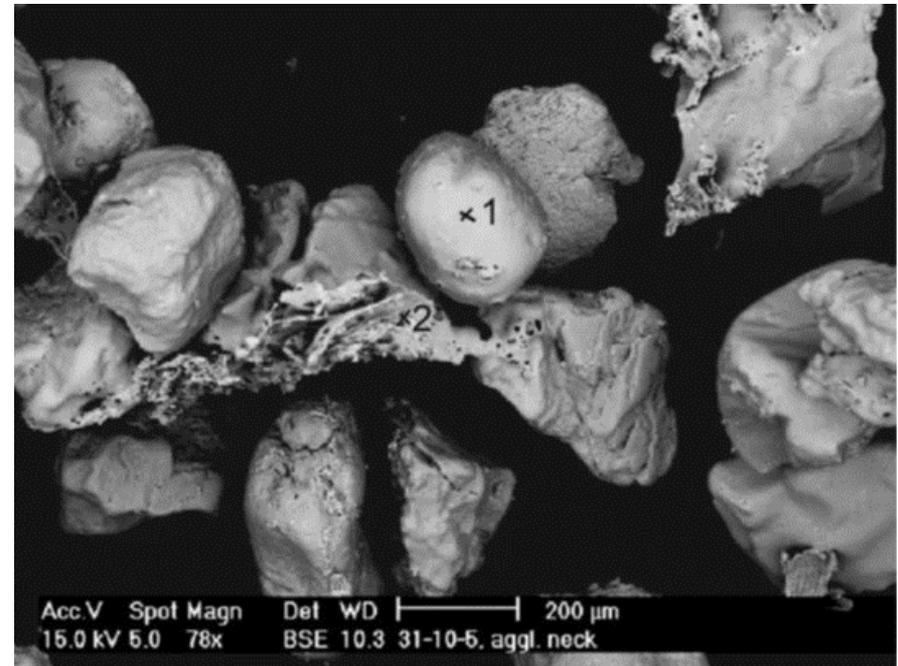
STAY IN CONTROL

Increase your profitability by burning challenging alkali fuels more efficiently

QUARTZ SAND, THE CURRENT MATERIAL OF CHOICE

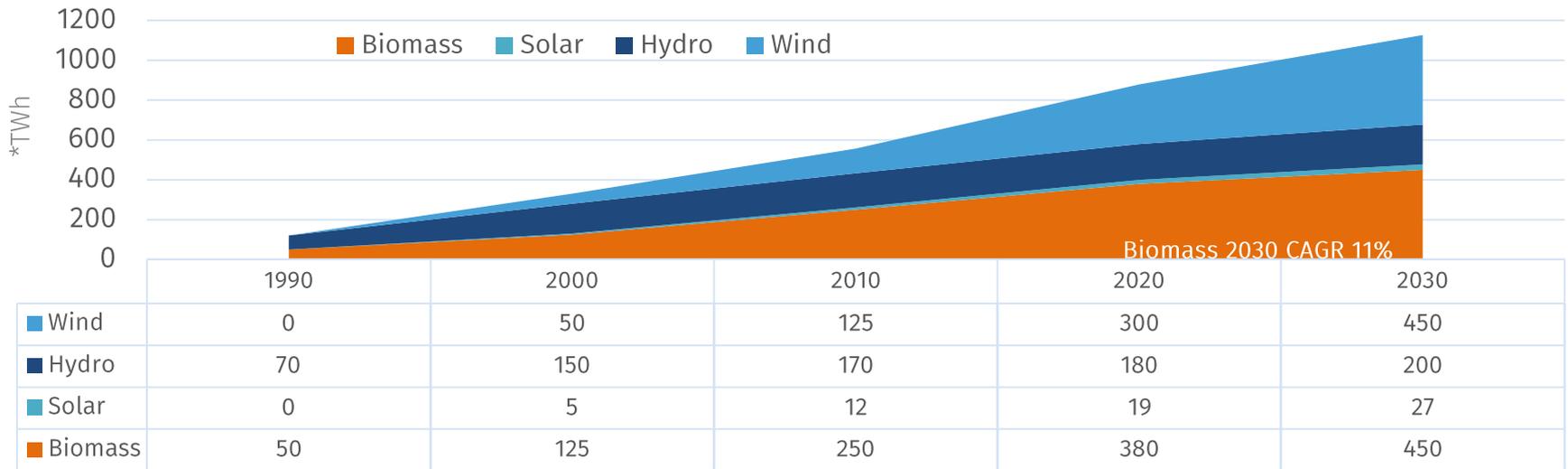
A reliable material for low risk fuels, but non-optimal for high alkali fuels

- ❖ Large majority of boilers today use quartz sand as a bed material.
- ❖ However: With an introduction of biomass fuels like straw, corn cobs, household waste and sludge boiler performance issues may surface.
- ❖ Alkalis present in the ashes from these fuels cause reactions between quartz sand and the ashes.
- ❖ Those reactions create a sticky “glue-like” substance binding bed material grains together and -as a consequence- lead to bed de-fluidization and costly outages.



THE FUTURE: GROWTH IN BIOENERGY

Europe's 2020 Energy Strategy will see bioenergy usage more than double within just 15 years



*TWh - TeraWatt hour

This increase in bioenergy means that availability of biomass fuels is changing



Mtoe: 83 Mt **2010**
 Agricultural Waste: 13 (16%)
 Domestic Waste: 6 (7%)
 Virgin Wood: 64 (77%)



Mtoe: 97 Mt **2015**
 Agricultural Waste: 18 (19%)
 Domestic Waste: 10 (10%)
 Virgin Wood: 69 (71%)



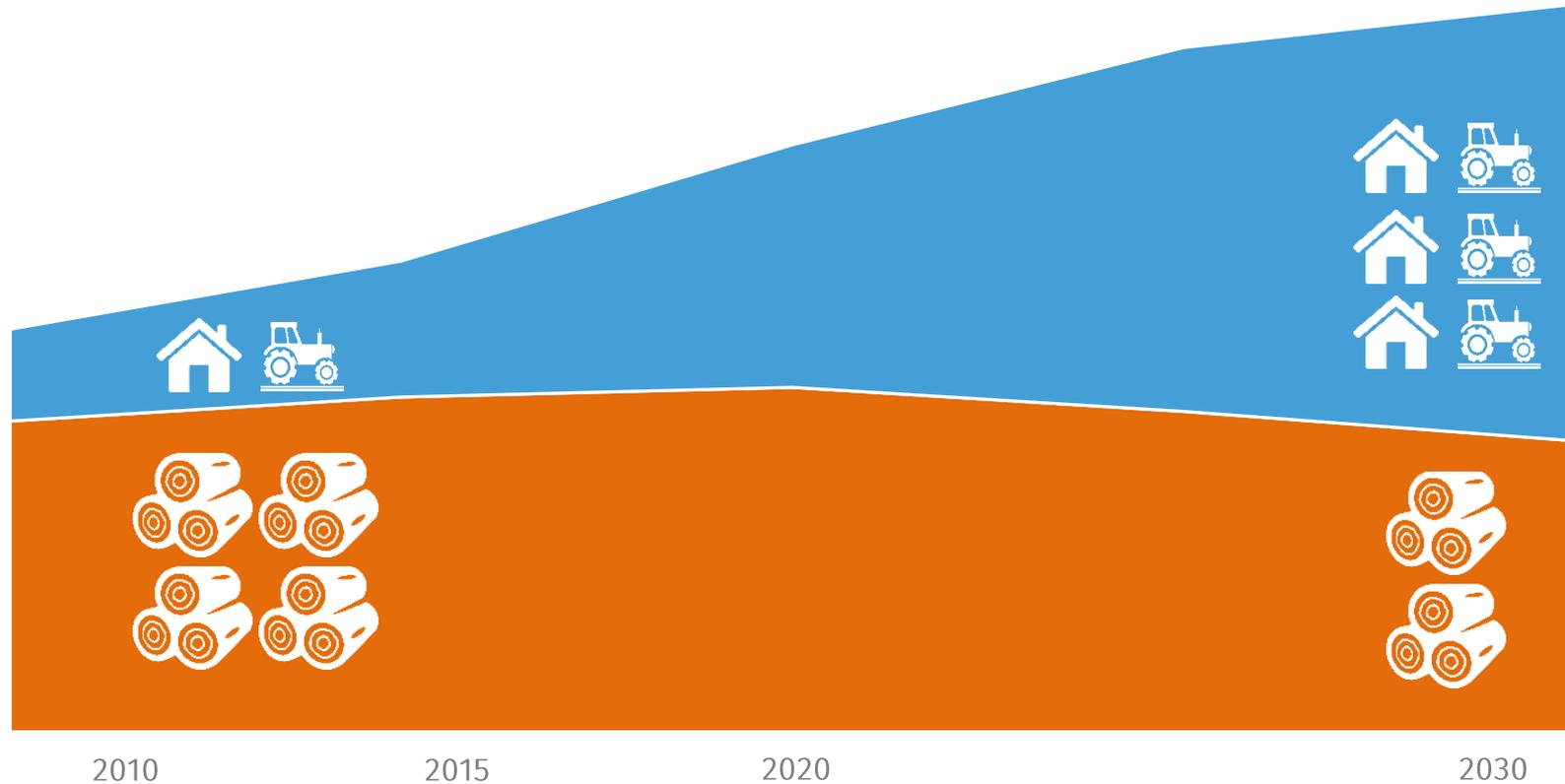
Mtoe: 121 Mt **2020**
 Agricultural Waste: 36 (30%)
 Domestic Waste: 14 (12%)
 Virgin Wood: 71 (59%)



Mtoe: 150 Mt **2030**
 Agricultural Waste: 70 (47%)
 Domestic Waste: 20 (13%)
 Virgin Wood: 60 (40%)

THIS MEANS

An increase of high alkali fuels entering your boiler



price of woodchips is increasing



increase in use of co-firing fuel



waste streams need to be processed in a more eco-friendly way

IMPACT OF CHANGING YOUR FUEL MIX

Combining the wrong fuels with the wrong bed materials can cause problems



	K, Na	Ca, Mg	P	Metals	Cl,F
SiO ₂	severe agglomeration and/or fouling			agglomeration / fouling	corrosion
K, Na		agglomeration / fouling	moderate fouling / agglomeration	agglomeration / fouling	severe corrosion
Ca, Mg			agglomeration / fouling	agglomeration / fouling	corrosion
P				agglomeration / fouling	corrosion
Metals					moderate corrosion

Findings from tests conducted with ECN (Energy Research Center: www.ecn.nl)

INTRODUCING **GREENFLOW**

Sibelco's new bed material solution to unwanted reactions in the boiler

Greenflow:

A magnesium iron silicate $(\text{Mg}^{+2}, \text{Fe}^{+2})_2\text{SiO}_4$ unresponsive to high alkali fuels

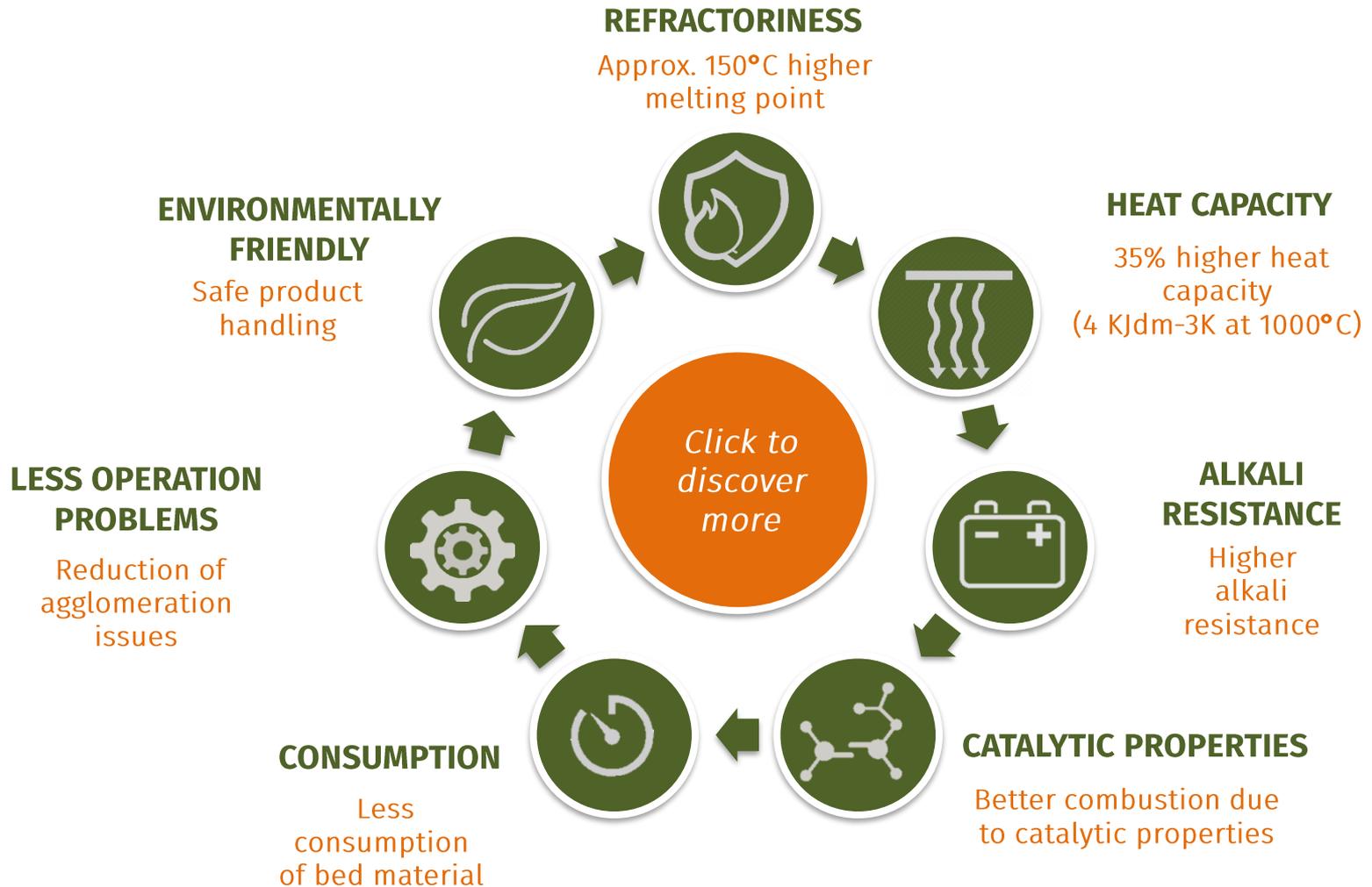
Chemical analysis %

MgO	49-50%	CaO	0,05-0,10%
SiO ₂	41,5-42,5%	Cr ₂ O ₃	0,2-0,3%
FeO + Fe ₂ O ₃	6,8-7,3%	MnO	0,05-0,1%
Al ₂ O ₃	0,4-0,5%	NiO	0,3-0,35%
Free silica < 1,0%			



BENEFITS OF GREENFLOW

Key advantages of Greenflow compared to normal bed material for challenging fuels



BENEFITS OF **GREENFLOW**

Increase your ratio of high alkali fuels with **Greenflow**

- ❖ Industrial scale tests show that an exchange of quartz sand with Greenflow allows for a 4x increase in share of high alkali biomass in the fuel mix.
- ❖ So, if the fuel contains 95% wood and 5% corncobs, Greenflow can allow a change of the fuel in some cases to 80% wood and 20% corncobs.

Performance of Biomass type and Greenflow bed material

Very efficient

- Safflower straw
- Walnut shells
- Macadamia shells
- Forest residue and energy crops as willow and poplar
- Corn Cobs

Efficient

- Non organic residue (cables, carpet residue, plastics)
- Rye straw
- RDF (Refuse-derived fuel)

Less benefits

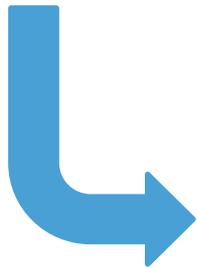
- Wheat straw
- Switch grass and other grasses
- Rapeseed residue
- Sunflower shells
- Sludge

HOW WE CAN COLLABORATE

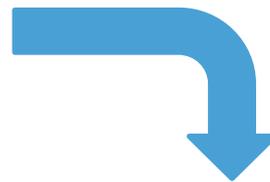
Keen to know how Greenflow can increase your boiler's performance and profitability?



1 We'll take a sample of your bed material, fuel and ash



2 Test & analyse it in our laboratory

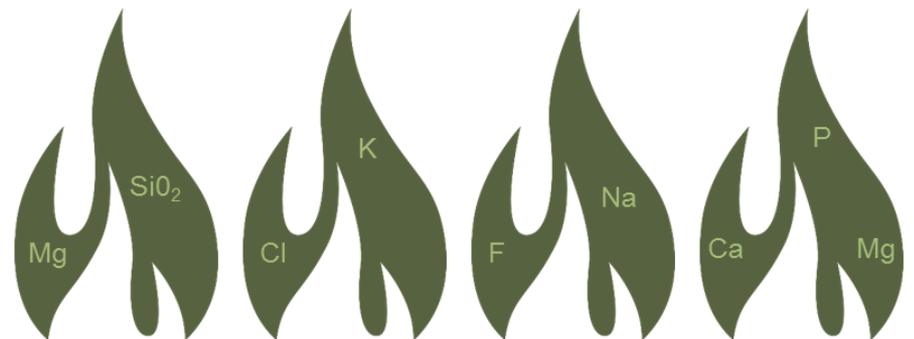


3 Discover the benefits Greenflow will bring

GREENFLOW

STAY IN CONTROL

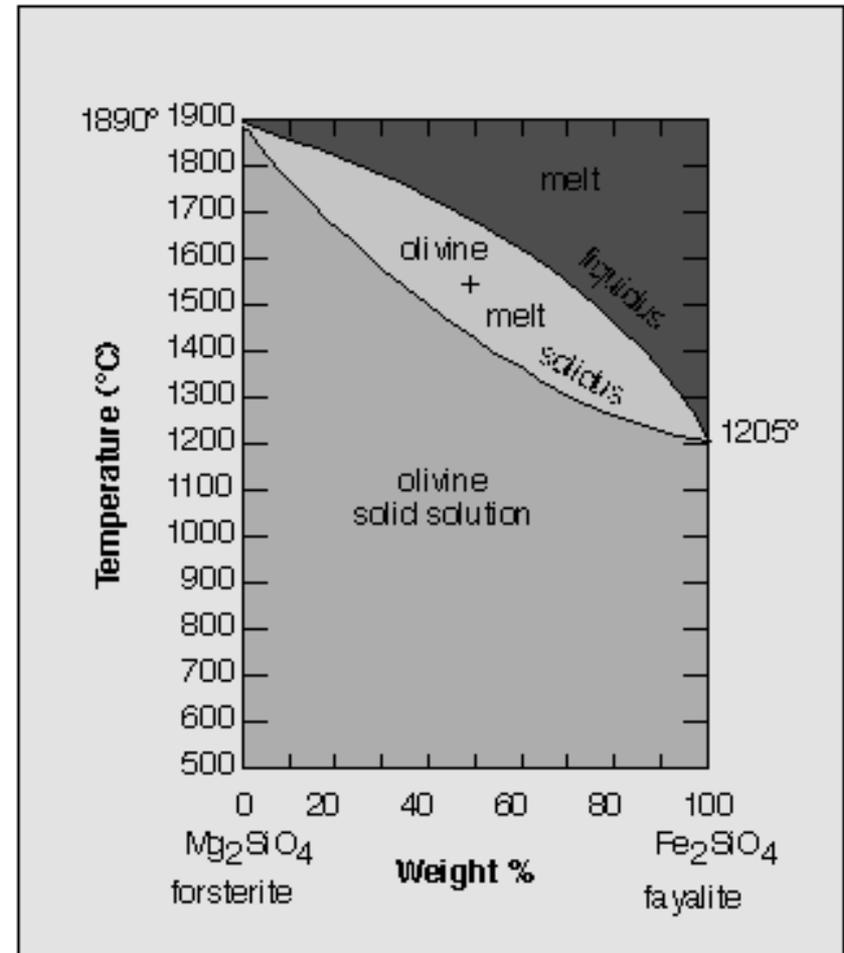
TECHNICAL DEEP DIVE



1. Refractoriness

Greenflow has a melting point that is approximately 150°C higher compared to quartz sand

- ❖ Sinter temperature (°C)
 - ❖ Olivine: 1 450 - 1 500°C
 - ❖ Quartz sand: 1 175 - 1 450 °C
(depending on SiO₂ purity)



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Benefits

2. Heat Capacity

35% higher heat capacity (4 KJdm⁻³K at 1000°C)

- ❖ Heat capacity or thermal capacity is a measurable physical quantity equal to the ratio of the heat added to (or removed from) an object to the resulting temperature change.
- ❖ A high heat capacity means a bed material particle can carry a high temperature throughout the boiler. The higher the capacity ensures sufficiently high heating rates and homogeneous temperature distribution (SLU, 2014)
- ❖ **Greenflow** has a higher heat capacity than quartz sand implicating a more stable material in the boiler
- ❖ Specific heat (cal/g °C)
 - ❖ Olivine: 0.30
 - ❖ Quartz sand: 0.27

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Benefits*

3. ALKALI RESISTANCE

Greenflow does not react with alkalis avoiding boiler issues common to silica-alkali reactions

- ❖ **Greenflow** is a magnesium iron silicate ($\text{Mg}^{+2}, \text{Fe}^{+2}$) 2SiO_4
- ❖ Because of its resistance to chemical reagents, the material is an important refractory material—i.e., it can be used in furnace linings and in kilns when other materials are subjected to heat and chemical processes.”

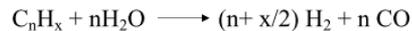
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4. CATALYTIC PROPERTIES

Catalytic properties result in significant reduction in tar formation in gasification processes and reduction in emission of hydrocarbons in combustion.

❖ **Greenflow** contains small quantities of known catalysts as Fe, Cr and Ni.

❖ For example Nickel catalyzes tar reforming



❖ Another example is: the gaseous mixture containing carbon monoxide, obtained from biomass containing an excess of steam, over an iron catalyst (for example iron metal or an iron oxide), reacts according to reaction:



❖ Here the iron catalyst shifts the CO/H₂ equilibrium in the favor of hydrogen gas.

Chemical analysis %

MgO	49-50%	CaO	0,05-0,10%
SiO ₂	41,5-42,5%	Cr ₂ O ₃	0,2-0,3%
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Benefits

5. CONSUMPTION

***Greenflow** needs less replacement than traditional silica bed materials when burning high alkali fuels*

- ❖ ***Greenflow*** shows less reactions with alkalis and has a higher melting point than traditional silica bed materials.
- ❖ As a result it is less sensitive to reactions with fuels or loss in performance of the bed material reducing the need to exchange the bed material.
- ❖ With lower exchange rate the consumption decreases.

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Benefits*

6. *Less operation problems*

Greenflow's properties bring additional benefits to boiler operations

Issues

- ❖ Agglomeration affecting boiler operations
 - ❖ One of the most troublesome consequences of interaction between ash-forming elements and bed material is agglomeration. In this process, bed material particles adhere to each other to form an agglomerate, which may prevent mixing in the bed or lead to defluidization (Skrifvars et al., 1994, Lin et al., 2003)
- ❖ Uneven heat distribution and heat transfer leading to additional heating requirements
 - ❖ The uniform temperature distribution renders less need for additional heating of the bed in order to ensure that a minimum temperature is reached in all bed regions, thus making a low process temperature possible. (Alvarez, 2006).

Benefits

- ❖ The properties of **Greenflow** such as the presence of Aluminium help prevent agglomeration / sintering as they form particles with a higher melting point (eg. reaction between potassium silicate and aluminium: alkali aluminosilicates) avoiding the formation agglomeration.
- ❖ **Greenflow** has a higher heat capacity than traditional silica bed materials resulting in a more stable combustion requiring less additional heating of the boiler

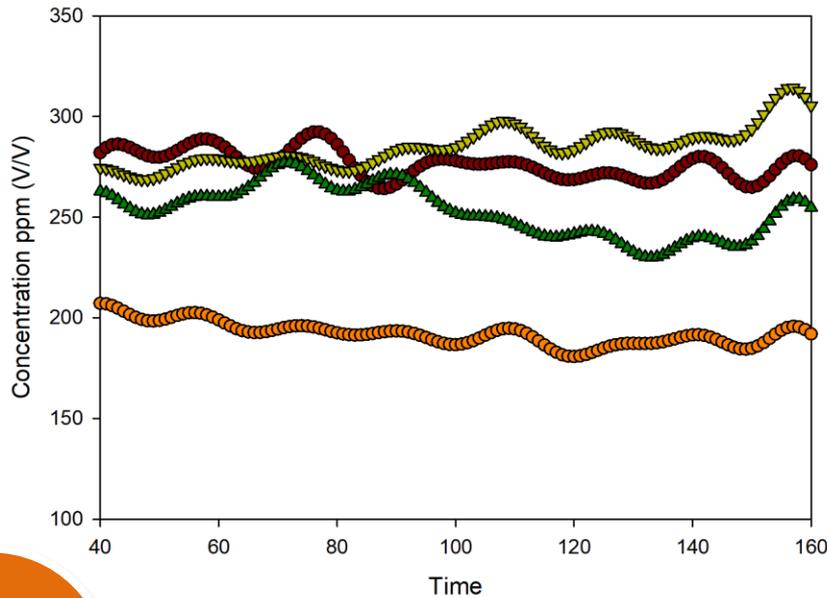
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7. Environmentally friendly

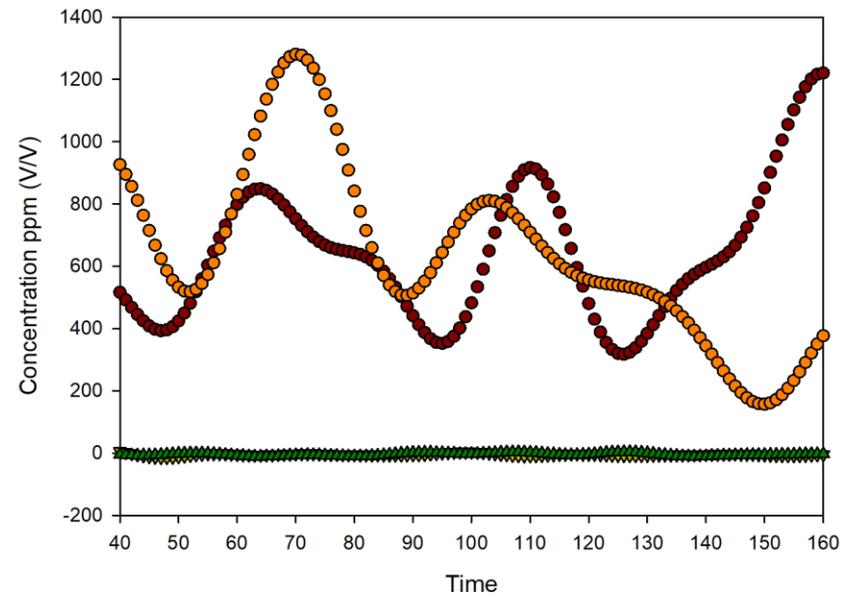
Less risk of silica related health issues and indications for less harmful emissions

- ❖ **Greenflow** does not contain respirable silica fraction. With quartz sand bed there is always risk of respirable silica occurrence. Even when fresh material is respirable silica free, fine silica particles can be created during process. Exposure to respirable silica can lead to silicosis.
- ❖ Testing indicates reduced emissions compared to other bed materials

Emission NOx



Emission CO



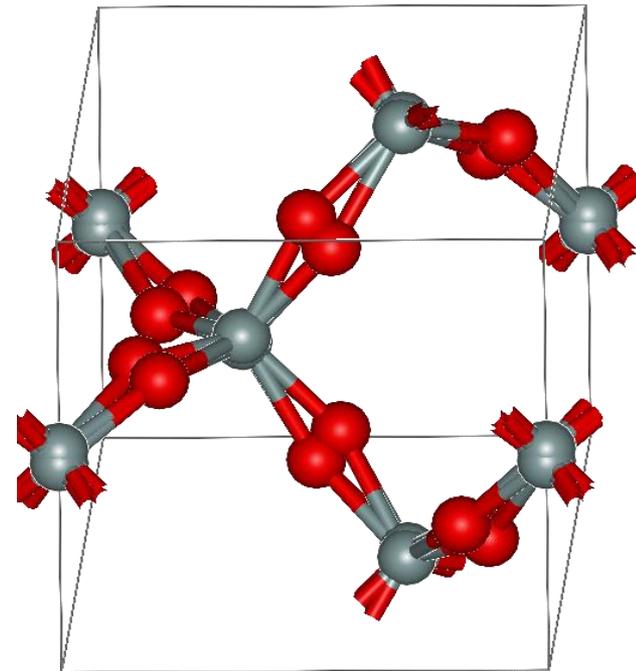
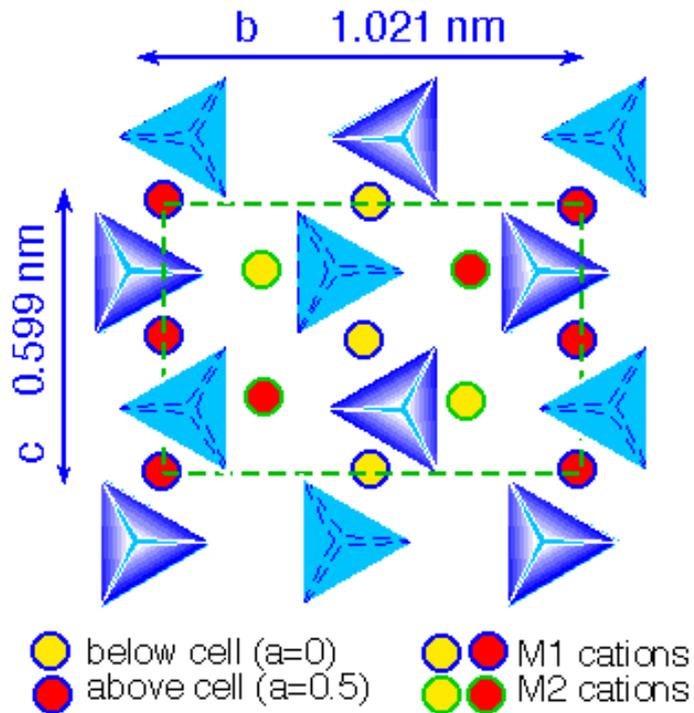
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—●— Sand
—○— Kaolin
—△— Ilmenite
—△— Greenflow

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CRYSTAL STRUCTURE

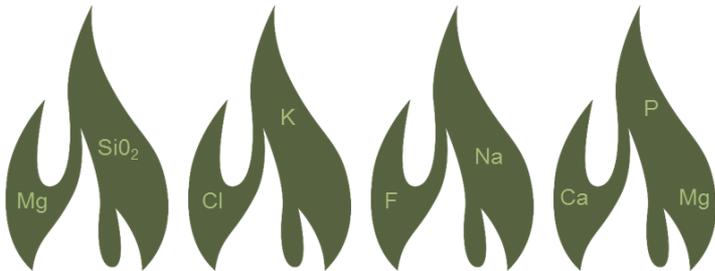
In the **Greenflow** group of minerals isolated $[SiO_4]$ tetrahedra are linked together by the other cations which lie between them.



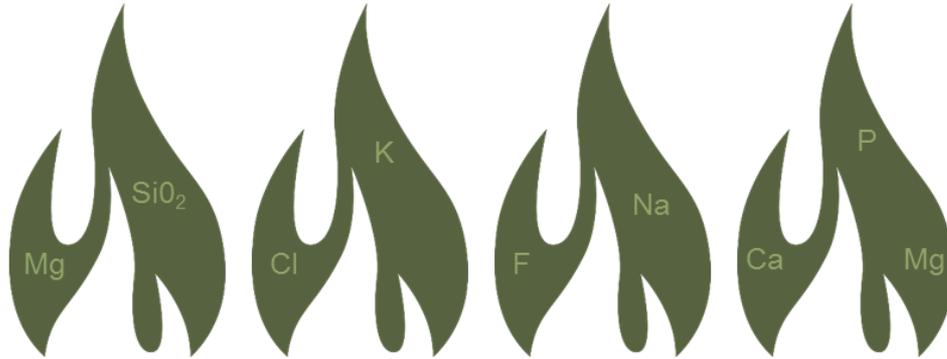
Key take-away

Greenflow allows you to increase your profitability by burning challenging alkali fuels more efficiently

Sibelco's new bed material – **Greenflow** – helps companies using CFB and BFB technology to combust high alkali biomass efficiently by reducing unwanted reactions between bed material and alkali fuels in the boiler and increase their profitability by consuming less bed material, increasing combustion efficiency due to catalytic properties and burning higher amounts of challenging biomass fuels than before.



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